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AGRICULTURAL TRACTORS

Roll-Over Protective Structures

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DEPARTMENT OF LABOR

Occupational Safety and Health Administration

[29 CFR Part 1928]

[S–74–2]

AGRICULTURAL TRACTORS

Roll-Over Protective Structures

Pursuant to section 6(b) of the Williams-Steiger Occupational Safety and Health Act of 1970 (29 U.S.C. 655), Secretary of Labor's Order No. 12–71 (36 FR 8754), and 29 CFR Part 1911, it is proposed to amend Chapter XVII of Title 29 of the Code of Federal Regulations by adding a new Part 1928 to contain a new occupational safety and health standard for roll-over protective structures for agricultural tractors.

Tractor roll-overs have been a major cause of employee injury and death on the farm. The Secretary of Labor recognized the need to deal with this problem, when, in appointing the Standards Advisory Committee on Agriculture in June 1971, he made the area of roll-over protective structures (ROPS) a priority subject for a standard.

The Standards Advisory Committee on Agriculture appointed a subcommittee on ROPS at its first meeting in July 1971. The subcommittee met in Washington, D.C. on October 18–19, 1972, and in Iowa City, Iowa on December 18–20, 1972. A final recommendation was presented by the subcommittee to the full committee on December 20, 1972, and was unanimously adopted. The proposed standard presented below is based substantially on the recommendation of the Standards Advisory Committee on Agriculture.

The basic requirements of the proposed standard are summarized as follows:

(1) The standard would require a tractor of over 20 engine horsepower used in agricultural operations to be equipped with a roll-over protective structure. The structure would be intended to protect employee operators from injury in tractor roll-overs.

(2) All ROPS devices would have to meet specified performance requirements, to be determined on the basis of certain tests which must be undergone by representative samples of all ROPS.

(3) Protective frame type ROPS (a structure generally composed of uprights mounted to a tractor, and extending above the operator's head), would have to be tested according to the requirements of § 1928.52. This section is an adaptation of American Society of Agricultural Engineers (ASAE) Standard 306.3, and of Society of Automotive Engineers (SAE) Standard J334, Protective Frame for Agricultural Tractors—Test Procedures and Performance Requirements, which were incorporated by the Standards Advisory Committee on Agriculture in its recommendation to the Assistant Secretary of Labor. It would require that a representative protective frame undergo either a static test (§ 1928.52(e)(2)) or a dynamic test (§ 1928.52(e)(3)), for frame strength. A field upset test may be required if the specified performance requirements of the static or dynamic tests are not exceeded.

(4) Representative protective enclosure type ROPS (a structure generally comprising of a frame and enclosure mounted to a tractor—see Fig. C–12), would have to be tested according to the requirements of § 1928.53. This section is an adaptation of ASAE S336.1 (SAE J168)—Protective Enclosures for Agricultural Tractors—Test Procedures and Performance Requirements, which was incorporated by the Standards Advisory Committee on Agriculture in its recommendation to the Assistant Secretary of Labor. It would require that a protective enclosure undergo either a static test (§ 1928:53(e)(2)) or a dynamic test (§ 1928.53(e)(3)). A field upset test may be required if the specified performance requirements of the static or dynamic tests are not exceeded.

(5) All tractors with ROPS would have to be provided with a seat belt. The specifications for seat belts are spelled out in § 1928.51(b)(2).

(6) The standard would require labeling of all roll-over protective structures, to give the following information: The name of the manufacturer, the type of tractor for which a particular device is designed, the date of manufacture, and the type of tests that the particular ROPS model has undergone.

(7) The standard would apply to all tractors used by employees in agricultural operations, that are manufactured on or after a stated date.

Written data, views, and arguments concerning the proposal may be mailed to the Office of Standards, Room 504, 400 First Street NW., Washington, D.C. 20210. All written submissions received before March 6, 1974 will be considered. The data, views, and arguments will be available for public inspection and copying at the Office of Standards.

Pursuant to 29 CFR 1911.11 (b) and (c), interested persons may, in addition to filing written matter as provided above, file objections to the proposal requesting an informal hearing with respect thereto, in accordance with the following conditions:

(1) The objections must include the name and address of the objector;

(2) The objections must be postmarked on or before March 6, 1974;

(3) The objections must specify with particularity the provision of the proposed standard to which the objections are taken, and must state the grounds therefor;

(4) Each objection must be separately stated and numbered; and

(5) The objections must be accompanied by a summary of the evidence proposed to be adduced at the requested hearing.

The new Part 1928 is proposed to read as follows:

PART 1928—OCCUPATIONAL SAFETY AND HEALTH STANDARDS FOR AGRICULTURE

Subpart A [Reserved]

Subpart B [Reserved]

Subpart C—Roll-Over Protective Structures

Sec.

1928.51 Roll-over protective structures (ROPS) for operators of tractors.
1928.52 Protective frame for agricultural tractors-test procedures and performance requirements.
1928.53 Protective enclosures for agricultural tractors-test procedures and performance requirements.

AUTHORITY: Sec. 6(b), Pub. L. 91–596, 84 Stat. 1593 (29 U.S.C. 655). Secretary of Labor's Order No. 12–71, 36 FR 8754.

Subpart A—[Reserved]

Subpart B—[Reserved]

Subpart C—Roll-over Protective Structures

§ 1928.51 Roll-over protective structures (ROPS) for operators of tractors.

(a) *Definitions.* As used in this subpart;

(1) *"Agricultural tractor"* means a two-or-four-wheel drive type vehicle, or track vehicle, of more than 20 engine horsepower, designed to furnish the power to pull, carry, propel, or drive implements that are designed for agriculture. All self-propelled implements are excluded.

(2) *"Tractor weight"* includes the protective frame or enclosure, all fuels, and other components required for normal use of the tractor. Ballast shall be added as necessary to achieve a minimum total weight of 110 lb. (50.0 kg.) per maximum power take-off horsepower at rated engine speed or the maximum gross vehicle weight specified by the manufacturer, whichever is greatest. Front end weight shall be at least 25 percent of the tractor test weight. In case power take-off horsepower is not available, 95 percent of net engine flywheel horsepower shall be used.

(b) *General requirements.* Agricultural tractors manufactured after August 31, 1974, shall meet the following requirements:

(1) *Roll-over protective structure.* A roll-over protective structure shall be provided that meets the appropriate performance requirements of § 1928.52, or § 1928.53, or of § 1926.1001 of this Chapter.

(2) *Seat belt.* A seat belt shall be provided by the employer, and required to be used by the employee, which conforms to Society of Automotive Engineers Standard SAE J4c, 1965 Motor Vehicle Seat Belt Assemblies, except as noted hereafter.

(i) Where a suspended seat is used, the seat belt shall be fastened to the movable portion of the seat to accommodate ride motion of the operator.

(ii) The seat belt anchorage shall be capable of withstanding a static tensile load of 1,000 pounds (453.6kg) at 45 degrees to the horizontal equally divided between the anchorages. The seat belt

mounting shall be capable of withstanding this load plus a load equal to four times the weight of all applicable seat components applied 45 degrees to the horizontal in a forward and upward direction. In addition, the seat mounting shall be capable of withstanding a 500 pound (226.8kg) belt load plus two times the weight of all applicable seat components both applied at 45 degrees to the horizontal in an upward and rearward direction. Floor and seat deformation is acceptable provided there is not structural failure or release of the seat adjuster mechanism or other locking device. The seat adjuster or locking device need not be operable after application of the test load.

(iii) The seat belt webbing material shall have a resistance to acids, alkalies, mildew, aging, moisture, and sunlight equal to or better than that of untreated polyster fiber.

(3) *Protection from spillage.* Batteries, fuel tanks, oil reservoirs, and coolant systems shall be constructed and located or sealed to assure that spillage will not occur which may come in contact with the operator.

(4) *Protection from sharp surfaces.* All sharp edges and corners at the operator's station shall be appropriately treated to minimize operator injury in the event of an upset.

(c) *Remounting.* ROPS removed for any reason, shall be remounted according to manufacturer's specifications.

(d) *Labeling.* Each ROPS shall have th following information permanently affixed to the structure:

(1) Manufacturer's or fabricator's name and address;

(2) ROPS model number, if any;

(3) Tractor make, model, or series number that the structure is designed to fit;

(4) Date of manufacture; and

(5) The tests (static, dynamic, field upset) as required under this Subpart, which were performed on that model ROPS device.

§ 1928.52 Protective frame for agricultural tractors—test procedures and performance requirements.

(a) *Purpose.* The purpose of this section is to establish the test and performance requirements for a protective frame designed for wheel type agricultural tractors to minimize the frequency and severity of operator injury resulting from accidental upsets during normal operations. General systems requirements for the protection of operators are specified in § 1928.51.

(b) *Types of tests.* All protective frames for agricultural tractors must be of a model which has been tested as follows:

(1) *Laboratory test.* A laboratory test, either static or dynamic, under repeatable and controlled loading, to permit analysis of the protective frame for compliance with the performance requirements of this standard.

(2) *Field upset test.* A field upset test under reasonably controlled conditions, both to the side and rear, to verify effectiveness of the protective system under actual dynamic conditions. If the analysis of the protective frame static energy absorption test results indicate that both FER_{is} and FER_{ir} (as defined in paragraph (d) (2) (ii) of this section), exceed 1.15, or if the analysis of the protective frame dynamic energy absorption test results indicate that the frame can withstand an impact of 15 percent greater than required for the tractor weight (as shown in Figure C–7), then the field upset test may be omitted.

(c) *Description*—(1) *Protective frame.* A protective frame is a structure generally comprised of uprights mounted to the tractor, extending above the operator's seat. A typical 2-post frame is shown in Figure C–1.

(2) *Overhead weather shield.* If an overhead weather shield is available for attachment to the protective frame, it may be in place during tests, providing it does not contribute to the strength of the protective frame.

(3) *Overhead falling object protection.* If an overhead falling object protection device is available for attachment to the protective frame, it may be in place during tests provided it does not contribute to the strength of the protective frame.

(d) *Test procedures*—(1) *General.* (i) The tractor weight used shall be that of the heaviest tractor model on which the protective frame is to be used. See § 1928.51(a) (2).

(ii) A new protective frame, and mounting connections of the same design, shall be used for conducting each static, dynamic or field upset test.

(iii) Instantaneous deflection shall be measured and recorded for each segment of the test. Minimum dimensions during tests are specified in paragraph (e) (1) (i) of this section.

(iv) Seat reference point (SRP in Fig. C–3) is that point where the vertical line that is tangent to the most forward point at the longitudinal seat centerline of the seat back, and the horizontal line that is tangent to the highest point of the seat cushion intersect in the longitudinal seat section. The seat reference point is to be determined with the seat unloaded and adjusted to the highest and most rearward position provided for seated operation of the tractor.

(v) Where the seat is off the longitudinal center, the frame loading shall be on the side with the least space between center line of seat and protective frame.

(vi) Low temperature characteristics of the protective frame or its material shall be demonstrated as specified in paragraph (e) (1) (ii) of this section.

(vii) Rear input energy tests (static, dynamic or field upset) need not be performed on frames mounted to tractors having 4 driven wheels and more than one-half their unballasted weight on the front wheels since this type of vehicle is not prone to rearward upset.

(viii) Accuracy table:

Measurements	*Accuracy*
Deflection or frame, inches (millimeters)	±5 percent of deflection measured.
Vehicle weight, pounds (kilograms)	±5 percent of the weight measured.
Force applied to frame, pounds (kilograms)	±5 percent of force measured.
Dimensions of critical zone, inches (millimeters).	±0.5 in (12.5 mm).

(2) *Static test procedure.* (i) The following test conditions shall be met:

(A) The laboratory mounting base shall be the tractor chassis, or its equivalent for which the protective frame is designed.

(B) The protective frame shall be instrumented with the necessary equipment to obtain the required load deflection data at the locations and directions specifies in Fig C–2 and C–3.

(C) If the protective frame is of a one or two upright design, mounting connections shall be instrumented with the necessary equipment to record the required force to be used in paragraph (d) (2) (iii) (E) of this section. Instrumentation shall be placed on mounting connections before installation load is applied.

(ii) The following definitions shall apply:

W = Tractor weight (see §1928.51(a)(2)) in lb. (W' in kg).
E_{is} = Energy input to be absorbed during side loading in ft-lb (E'_{is} in m-kg).
$E_{is} = 723 + 0.4\ W$ ($E'_{is} = 100 + 0.12\ W'$).
E_{ir} = Energy input to be absorbed during rear loading in ft-lb (E'_{ir} in m-kg).
$E_{ir} = 0.47\ W$ ($E'_{ir} = 0.14\ W'$).
L = Static load, lb. (kg).
D = Deflection under L, in. (mm).
L–D = Static load-deflection diagram.
L_{max} = Maximum observed static load.
Load Limit = Point on a continuous L–D curve where observed static load is 0.8 L_{max} on down slope of curve (refer to Fig. C–5).
E_u = Strain energy absorbed by the frame, ft-lb (m-kg) Area under L–D curve.

$$FER_{is} = \text{Factor of energy ratio } FER_{is} = \frac{E_u}{E_{is}};$$

$$FER_{ir} = \frac{E_u}{E_{ir}}.$$

[1] P_b = Maximum observed force in mounting connection under static load, L, lb. (kg).
[1] P_u = Ultimate force capacity of mounting connection, lb. (kg).
[1] FSB = Design margin for mounting connection.

$$FSB = \frac{P_u}{P_b}.$$

[1] See paragraph (d) (2) (i) (C) of this section.

(iii) The test procedures shall be as follows:

(A) Apply the rear load as shown in Fig. C–3 and record L and D simultaneously. Rear load application shall be uniformly distributed on the frame over an area perpendicular to the direction of load application, no greater than 160 sq. in. (1032 sq. cm.) in size, with the largest dimension no greater than 27 inches (686 mm). The load shall be applied to the upper extremity of the frame at the point which is midway between the center of the frame and the inside of the frame upright. If no structural cross member exists at the rear of the frame, a substitute test beam which does not add strength to the frame may be utilized to complete this test procedure. Stop test when:

(*1*) The strain energy absorbed by the frame is equal to or greater than the required input energy E_{ir} or;

(2) Deflection of the frame exceeds the allowable deflection (See paragraph (e) (1) (i) of this section) or;

(3) Frame load limit (see Figure C–5) occurs before the allowable deflection is reached in rear load.

(B) Using data obtained in paragraph (d) (2) (iii) (A) of this section, construct the *L–D* diagram as shown typically in Fig. C–5.

(C) Calculate E_{ir}.

(D) Calculate FER_{ir}.

(E) Calculate *FSB*.

(F) Apply the side load tests on the same frame and record *L* and *D* simultaneously. Side load application shall be at the upper extremity of the frame at a 90 degree angle to the center line of the vehicle. The side load shall be applied to the longitudinal side farthest from the point of rear load application. Apply side load L as shown in Fig. C–2. Stop test when:

(*1*) The strain energy absorbed by the frame is equal to or greater than the required input energy E_{is} or;

(2) Deflection of the frame exceeds the allowable deflection (see paragraph (e) (1) (i) of this section) or;

(3) Frame load limit (see Figure C–5) occurs before the allowable deflection is reached in side load.

(G) Using data obtained in paragraph (d) (2) (iii) (F) of this section construct the L–D diagram as shown typically in Fig. C–5.

(H) Calculate E_{is}.

(I) Calculate FER_{is}.

(J) Calculate FSB.

(3) *Dynamic test procedure.* (i) The following test conditions shall be met:

(A) The protective frame and tractor shall be tested at the weight as defined in § 1928.51(a) (2).

(B) The dynamic loading shall be accomplished by use of a 4410 lb. (2000 kg) weight acting as a pendulum. The impact face of the weight shall be 27±1 in. by 27±1 in. (686±25 mm by 686±25 mm) and shall be constructed so that its center of gravity is within 1 in. (25.4 mm) of its geometric center. The weight shall be suspended from a pivot point 18 to 22 ft. (5.5–6.7 m) above the point of impact on the frame and shall be conveniently and safely adjustable for height. (See Fig. C–6).

(C) For each phase of testing, the tractor shall be restrained from moving when the dynamic load is applied. The restraining members shall have strength no less than, and elasticity no greater than, that of 0.50 in. (12.7 mm) steel cable. Points of attachment of restraining members shall be located an appropriate distance behind the rear axle and in front of the front axle to provide a 15 to 30 degree angle between a restraining cable and the horizontal. For the impact from the rear, the restraining cables shall be located in the plane in which the center of gravity of the pendulum will swing, or alternatively, two sets of symmetrically located cables may be used at convenient lateral locations on the tractor. For impact from the side, restraining cables shall be used as shown in Figures C–8 and C–9.

(D) The front and rear wheel tread settings, where adjustable, shall be at the position nearest to halfway between the minimum and maximum settings obtainable on the vehicle. Where only two settings are obtainable, the minimum setting shall be used. The tires have no liquid ballast and shall be inflated to the maximum operating pressure recommended by the manufacturer. With specified tire inflation, the restraining cable shall be tightened to provide tire deflation of 6 to 8 percent of nominal tire section width. After the vehicle is properly restrained, a wooden beam no less than 6 x 6 in. (150 x 150 mm) cross section shall be driven tightly against the appropriate wheels and clamped. For the test to the side, an additional wooden beam shall be placed as a prop against the wheel nearest the operator's station and shall be secured to the base so that it is held tightly against the wheel rim during impact. The length of this beam shall be chosen so that it is at an angle of 25 to 40 degrees to the horizontal when it is positioned against the wheel rim. It shall have a length 20 to 25 times its depth and a width 2 to 3 times its depth. (See Figs. C–8 and C–9).

(E) Means shall be provided for indicating the maximum instantaneous deflection along the line of impact. A simple friction device is illustrated in Fig. C–4.

(F) No repairs or adjustments shall be made during the test.

(G) If any cables, props, or blocking shift or break during the test, the test shall be repeated.

(ii) H=Vertical height of center of gravity of 4410 lb. (2000 kg) weight in inches (H' in mm). The weight shall be pulled back so that the height of its center of gravity above the point of impact is defined as follows:

$H=4.92+0.00190\ W$ or $(H'=125+0.107\ W')$ — (Fig. C–7).

(iii) The test procedures shall be as follows:

(A) The frame shall be evaluated by imposing dynamic loading from the rear followed by a load to the side on the same frame. The pendulum swinging from the height determined by paragraph (d) (3) (ii) of this section imposes the dynamic load. The position of the pendulum shall be so selected that the initial point of impact on the frame shall be in line with the arc of travel of the center of gravity of the pendulum. A quick release mechanism may be used but shall not influence the attitude of the block.

(B) Impact at rear: The tractor shall be properly restrained as per paragraphs (d) (3) (i) (C) and (d) (3) (i) (D) of this section. The tractor shall be positioned with respect to the pivot point of the pendulum so that the pendulum is 20 degrees from the vertical prior to impact as shown in Fig. C–8. The impact shall be applied to the upper extremity of the frame at the point which is midway between the center line of the frame and the inside of the frame upright. If no structural cross member exists at the rear of the frame, a substitute test beam which does not add to the strength of the frame may be utilized to complete the test procedure.

(C) Impact at side: The blocking and restraining shall conform to paragraphs (d) (3) (i) (C) and (d) (3) (i) (D) of this section. The point of impact shall be at the upper extremity of the frame at a point most likely to hit the ground first and at a 90 degree angle to the center line of the vehicle as shown in Fig. C–9. The side impact shall be applied to the longitudinal side farthest from the point of rear impact.

(4) *Field upset test procedure.* (i) The following test conditions shall be met:

(A) The tractor shall be tested at the weight as defined in § 1928.51(a) (2).

(B) The test shall be conducted on a dry, firm soil bank. The soil in the impact area shall have an average cone index in the 0 to 6 in. (0 to 152 mm) layer not less than 150. Cone index is defined in American Society of Agriculture Engineers Recommendation ASAE R313, Soil Cone Penetrometer. The path of vehicle travel shall be 12±2 degrees to the top edge of the bank.

(C) An 18 in. (457 mm) high ramp as described in Fig. C–10 shall be used to assist in upsetting the vehicle to the side.

(D) The front and rear wheel tread settings, where adjustable, shall be at the position nearest to halfway between the minimum and maximum settings obtainable on the vehicle. Where only two settings are obtainable, the minimum setting shall be used.

(ii) Field upsets shall be induced to the rear and side.

(A) Rear upset shall be induced by engine power with the tractor operating in a gear to obtain 3 to 5 MPH (4.8 to 8.0 km per hour) at maximum governed engine rpm preferably by driving forward directly up a minimum slope of 60°±5° as shown in Fig. C–11. The engine clutch may be used to aid in inducing the upset.

(B) To induce side upset, the tractor shall be driven under its own power along the specified path of travel at a minimum speed of 10 MPH (16 km per

hour), or at maximum vehicle speed if under 10 MPH (16 km per hour), and over the ramp as described in paragraph (d)(4)(i)(C) of this section.

(e) *Performance requirements*—(1) *General requirements.* (i) The frame, overhead weather shield, fenders, or other parts in the operator area may be deformed in these tests but shall not shatter or leave sharp edges exposed to the operator, or encroach on the dimensions shown in Figs. C–2 and C–3 as follows:

d=2 in. (51 mm) inside of frame upright to vertical center line of seat.
e=30 in. (762 mm) at the longitudinal centerline.
f=Not greater than 4 in. (102 mm) to rear edge of crossbar, measured forward of the seat reference point (SRP).
g=24 in. (610 mm) minimum.
m=Not greater than 12 in. (305 mm) measured from SRP to forward edge of crossbar.

(ii) The protective structure and connecting fasteners must pass the dynamic tests described in paragraph (d)(3) or (4) of this section at a metal temperature of 0 degrees Fahrenheit or below, or exhibit Charpy V-notch impact strengths per the following:

10 mm x 10 mm specimen: 8 ft.-lb. at −20° F. (10.8J at −30° C).
10 mm x 5 mm specimen: 5 ft.-lb. at −50° F (6.8J at −45° C).
10 mm x 2.5 mm specimen: 2 ft.-lb. at −70° F (2.7J at −57° C).

(Reference: ASTM A370–68, "Standard Methods and Definitions for Mechanical Testing of Steel Products.")

Specimens are to be "longitudinal" and taken from flat stock, tubular, or structural sections before forming or welding for use in the frame. Specimens from tubular or structural sections are to be taken from the middle of the side of greatest dimension, not to include welds.

(2) *Static test performance requirements.* The structural requirements will be generally met if the FER>1 and FSB>1.3 (FSB>1.3 applicable to 1 or 2 upright frames only) and the requirements contained in paragraph (e)(1) of this section are adhered to in both side and rear loads.

(3) *Dynamic test performance requirements.* The structural requirements will be generally met if the dimensions in paragraph (e)(1) of this section are adhered to in both side and rear loads.

(4) *Field upset test performance requirements.* The requirements of paragraph (e)(1) of this section must be met in both side and rear upsets.

§ 1928.53 Protective enclosures for agricultural tractors—test procedures and performance requirements.

(a) *Purpose.* The purpose of this section is to establish the test and performance requirements for a protective enclosure designed for wheel type agricultural tractors to minimize the frequency and severity of operator injury resulting from accidental upset during normal operations. General requirements for the protection of operators are specified in § 1928.51.

(b) *Types of tests.* All protective enclosures for agricultural tractors must be of a model which has been tested as follows:

(1) *Laboratory test.* A laboratory test, either static or dynamic, under repeatable and controlled loading, to permit analysis of the protective enclosure for compliance with the performance requirements of this standard.

(2) *Field upset test.* A field upset test under reasonably controlled conditions, both to the side and rear, to verify effectiveness of the protective system under actual dynamic conditions. If the analysis of the protective frame static energy absorption test results indicate that both FER_{is} and FER_{ir} (as defined in paragraph (d)(2)(ii) of this section) exceed 1.15, or if the analysis of the protective frame dynamic energy absorption test results indicate that the frame can withstand an impact 15 percent greater than required for the tractor weight (as shown in Fig. C–7), then the field upset test may be omitted.

(c) *Description.* A protective enclosure is a structure generally comprising a frame and/or enclosure mounted to the tractor and conforming generally to Fig. C–12.

(d) *Test Procedures*—(1) *General.* (i) The tractor weight used shall be that of the heaviest tractor model on which the protective enclosure is to be used. See § 1928.51(a)(2).

(ii) A new protective enclosure (structural members of cab) and mounting connections of the same design shall be used for conducting each static, dynamic or field upset test.

(iii) Instantaneous deflection shall be measured and recorded for each segment of the test. Minimum dimensions during tests are specified in paragraph (d)(1)(i) of this section.

(iv) Seat reference point (SRP in Fig. C–14) is that point where the vertical line that is tangent to the most forward point at the longitudinal seat centerline of the seat back, and the horizontal line that is tangent to the highest point of the seat cushion intersect in the longitudinal seat section. The seat reference point is to be determined with the seat unloaded and adjusted to the highest and most rearward position provided for seated operations of the tractor.

(v) Where the seat is off the longitudinal center, the protective enclosure loading shall be on the side with least space between center line of seat and the protective structure.

(vi) Low temperature characteristics of the protective enclosure or its material shall be demonstrated as specified in paragraph (e)(1)(ii) of this section.

(vii) Rear input energy tests (static, dynamic or field upset) need not be performed on enclosures mounted to tractors having 4 driven wheels and more than one-half their unballasted weight on the front wheels since this type of vehicle is not prone to rearward upset.

(viii) Accuracy table:

Measurements	*Accuracy*
Deflection of enclosure, inches (millimeters)	±5 percent of deflection measured.
Vehicle weight, pounds (kilograms)	±5 percent of the weight measured.
Force applied to frame, pounds (kilograms)	±5 percent of force measured.
Dimensions of critical zone, inches (millimeters.)	±0.5 in. (12.5 mm).

(ix) Where movable or normally removable portions of the enclosure add to structural strength, they shall be placed in configurations that contribute least to the structural strength during the test.

(2) *Static test procedure.* (i) The following test conditions shall be met:

(A) The laboratory mounting base shall be the tractor chassis, or its equivalent, for which the protective enclosure is designed.

(B) The protective enclosure shall be instrumented with the necessary equipment to obtain the required load deflection data at the locations and directions as specified in Figs. C–13 and C–14.

(ii) The following definitions shall apply:

W=Tractor weight (see § 1928.51(a)(2)) in lb. (W' in kg.)
E_{is}=Energy input to be absorbed during side loading in ft-lb. (E'_{is} in m-kg)
E_{is}=723+0.4 W (E'_{is}=100+0.12 W')
E_{ir}=Energy input to be absorbed during rear loading in ft-lb. (E'_{ir} in m-kg)
E_{ir}=0.47 W (E'_{ir}=0.14 W')
L=Static load, lb. (kg)
D=Deflection under L, in. (mm)
L-D=Static load-deflection diagram
L_{max}=Maximum observed static load.
Load Limit=Point on a continuous L-D curve where observed static load is 0.8 L_{max} on down slope of curve (refer to Fig. C–16)
E_u=Strain energy absorbed by the protective enclosure, ft-lb. (m-kg). Area under L-D curve.
FER=Factor of energy ration $FER_{is}=\frac{E_u}{E_{is}}$:
$FER_{ir}=\frac{E_{iu}}{E_{ir}}$.

(iii) The test procedures shall be as follows:

(A) When the protective frame structures are not an integral part of the enclosure, the direction and point of load application for both side and rear shall be the same as specified in § 1928.52(d)(2).

(B) When the protective frame structures are an integral part of the enclosure apply the rear load as per Fig. C–14 and record L and D simultaneously. Rear load application shall be uniformly distributed on the frame structure over an area perpendicular to the load application, no greater than 160 sq. in. (1032 sq. cm.) in size with a largest dimension no greater than 27 in. (686 mm). The load shall be applied to the upper extremity of the structure at the point which is midway between the center line of the protective enclosure and the inside of the protective structure. If no structural cross member exists at the rear of the enclosure, a substitute test beam which does not add strength to the structure may be utilized to complete this test procedure. Stop test when:

(*1*) the strain energy absorbed by the structure is equal to or greater than the required input energy E_{tr}, or;

(*2*) deflection of the structure exceeds the allowable deflection (see paragraph (e) (1) (i) of this section) or;

(*3*) the structure load limit (see Fig. C–16) occurs before the allowable deflection is reached in rear load.

(C) Using data obtained in paragraph (d) (2) (iii) (B) of this section, construct the *L–D* diagram for rear loads as shown typically in Fig. C–16.

(D) Calculate E_{tr}.

(E) Calculate FER_{tr}.

(F) When the protective frame structures are an integral part of the enclosure apply the side load as shown in Fig. C–13 and record *L* and *D* simultaneously. Static side load application shall be uniformly distributed on the frame over an area perpendicular to the direction of load application, and no greater than 160 sq. in. (1032 sq. cm.) in size, with a largest dimension no greater than 27 in. (686 mm). Side load application shall be at a 90 degree angle to the center line of the vehicle. The center of side load application shall be located between a point "k", 24 in. (610 mm) forward; and a point "l", 12 in. (305 mm) rearward of the seat reference point to best utilize the structural strength (see Fig. C–13). This side load shall be applied to the longitudinal side farthest from the point of rear load application. Stop test when:

(*1*) the strain energy absorbed by the structure is equal to or greater than the required input energy E_{ts}, or;

(*2*) deflection of the structure exceeds the allowable deflection, (See paragraph (e) (1) (i) of this section) or;

(*3*) the structure load limit (See Figure C–16) occurs before the allowable deflection is reached in side load.

(G) Using data obtained in (d) (2) (iii) (F) construct the *L–D* diagram for side load as shown typically in Fig. C–16.

(H) Calculate E_{ts}.

(I) Calculate FER_{ts}.

(3) *Dynamic test procedure.* (i) The following test conditions shall be met:

(A) The protective enclosure and tractor shall be tested at the weight defined in § 1928.51(a) (2).

(B) The dynamic loading shall be accomplished by use of a 4410 lb. (2000 kg) weight acting as a pendulum. The impact face of the weight shall be 27±1 in. by 27±1 in. (686±25 mm by 686 ±25 mm) and shall be constructed so that its center of gravity is within 1 in. (25.4 mm) of its geometric center. The weight shall be suspended from a pivot point 18 to 22 ft. (5.5–6.7 m) above the point of impact on the enclosure and shall be conveniently and safely adjustable for height. (See Fig. C–17)

(C) For each phase of testing, the tractor shall be restrained from moving when the dynamic load is applied. The restraining members shall have strength no less than, and elasticity no greater than that of 0.50 in. (12.7 mm) steel cable. Points of attachment of restraining members shall be located an appropriate distance behind the rear axle and in front of the front axle to provide a 15 to 30 degree angle between a restraining cable and the horizontal. For the impact from the rear, the restraining cables shall be located in the plane in which the center of gravity of the pendulum will swing, or alternatively, two sets of symmetrically located cables may be used at convenient lateral locations on the tractor. For the impact from the side, restraining cables shall be used as shown in Figures C–19 and C–20.

(D) The front and rear wheel tread settings, where adjustable, shall be at the position nearest to halfway between the minimum and maximum settings obtainable on the vehicle. Where only two settings are obtainable, the minimum setting shall be used. The tires shall have no liquid ballast and shall be inflated to the maximum operating pressure recommended by the manufacturer. With specified tire inflation, the restraining cable shall be tightened to provide tire deflection of 6 to 8 percent of nominal tire section width. After the vehicle is properly restrained, a wooden beam no smaller than 6 x 6 in. (150 x 150 mm) cross-section shall be driven tightly against the appropriate wheels and clamped. For the test to the side, an additional wooden beam shall be placed as a prop against the wheel nearest the operator's station and shall be secured to the base so that it is held tightly against the wheel rim during impact. The length of this beam shall be chosen so that it is at an angle of 25 to 40 degrees to the horizontal when it is positioned against the wheel rim. It shall have a length 20 to 25 times its depth and width 2 to 3 times its depth. (See Figs. C–19 and C–20.)

(E) Means shall be provided for indicating the maximum instantaneous deflection along the line of impact. A simple friction device is illustrated in Fig. C–15.

(F) No repairs or adjustments shall be made during the test.

(G) If any cables, props, or blocking shift or break during the test, the test shall be repeated.

(ii) H=Vertical height of center of gravity of 4410 lb. (2000 kg) weight in inches (H' in mm). The weight shall be pulled back so that the height of its center of gravity above the point of impact is defined as follows:

$H=4.92+0.00190$ or $H'=125+0.107$ W')
(Fig. C–18)

(iii) The test procedures shall be as follows:

(A) The enclosure structure shall be evaluated by imposing dynamic loading from the rear followed by a load to the side on the same enclosure structure. The pendulum swinging from the height determined by paragraph (d) (3) (ii) of this section imposes the dynamic load. The position of the pendulum shall be so selected that the initial point of impact on the protective structure shall be in line with the arc of travel of the center of gravity of the pendulum. A quick release mechanism may be used but shall not influence the attitude of the block.

(B) *Impact at rear.* The tractor shall be properly restrained as per paragraph (d) (3) (i) (C) and (d) (3) (i) (D) of this section. The tractor shall be positioned with respect to the pivot point of the pendulum so that the pendulum is 20 degrees from the vertical prior to impact as shown in Fig. C–19. The impact shall be applied to the upper extremity of the enclosure structure at the point which is midway between the center line of the enclosure structure and the inside of the protective structure. If no structural cross member exists at the rear of the enclosure structure, a substitute test beam which does not add to the strength of the structure may be utilized to complete the test procedure.

(C) *Impact at side.* The blocking and restraining shall conform to paragraph (d) (3) (i) (C) and (d) (3) (i) (D) of this section. The center point of impact shall be at the upper extremity of the enclosure at a 90° angle to the center line of vehicle and located between a point "k", 24 in. (610 mm) forward, and a point "l", 12 in. (305 mm) rearward of the seat reference point, to best utilize the structural strength. (See Fig. C–13). The side impact shall be applied to the longitudinal side farthest from the point of rear impact.

(4) *Field upset test procedure.* (i) The following test conditions shall be met:

(A) The tractor shall be tested at the weight as defined in § 1928.52(a) (2).

(B) The test shall be conducted on a dry, firm soil bank. The soil in the impact area shall have an average cone index in the 0 to 6 in. (0 to 152 mm) layer not less than 150. Cone index is defined in American Society of Agricultural Engineers Recommendation ASAE R313, Soil Cone Penetrometer. The path of vehicle travel shall be 12±2 degrees to the top edge of bank.

(C) An 18 in. (457 mm) high ramp as described in Fig. C–21 shall be used to assist in upsetting the vehicle to the side.

(D) The front and rear wheel tread settings, where adjustable, shall be at the position nearest to halfway between the minimum and maximum settings obtainable on the vehicle. Where only two

settings are obtainable, the minimum setting shall be used.

(ii) Field upsets shall be induced to the rear and side.

(A) Rear upset shall be induced by engine power with the tractor operating in a gear to obtain 3 to 5 mph (4.8 to 8.0 km per hour) at maximum governed engine rpm, preferably by driving parward directly up a minimum slope of 60°±5° as shown in Fig. C–22. The engine clutch may be used to aid in inducing the upset.

(B) To induce side upset, the tractor shall be driven under its own power along the specified path of travel at a minimum speed of 10 mph (16 km per hour), or at maximum vehicle speed if under 10 mph (16 km per hour), and over the ramp as described in paragraph (d)(4)(i)(C) of this section.

(e) *Performance requirements*—(1) *General requirements.* (i) The protective enclosure structural members or other parts in the operator area may be deformed in these tests but shall not shatter or leave sharp edges exposed to the operator. They shall not encroach on a transverse plane passing through points d and f within the projected area defined by dimensions d, e and g or on the dimensions shown in Figs. C–13, and C–14, as follows:

b=3 in. (76 mm) rear of seat reference point in horizontal plane at the longitudinal center line.
d=2 in. (51 mm) inside of protective structure to vertical center line of seat.
e=30 in. (762 mm) at the longitudinal centerline.
f=not greater than 4 in. (102 mm) measured forward of seat reference point (SRP) at the longitudinal centerline as shown in Fig. C–14.
g=24 in. (610 mm) minimum.
h=17.5 in. (445 mm) minimum.
j=2.0 in. (51 mm) measured from outer periphery of steering wheel.

(ii) The protective structure and connecting fasteners must pass the dynamic tests described in paragraph (e)(3) or (e)(4) of this section at a metal temperature of 0 degrees Farenheit or below, or exhibit Charpy V-notch impact strengths per the following:

10 mm x 10 mm specimen; 8 ft.-lb. at −20° F. (10.8J at −30° C)
10 mm x 5 mm specimen; 5 ft.-lb. at −50° F. (6.8J at −45° C)
10 mm x 2.5 mm specimen; 2 ft.-lb. at −70° F. (2.7J at −57° C)
(Reference: ASTM A370–68, "Standard Methods and Definitions Mechanical Testing of Steel Products.")

Specimens are to be "longitudinal" and taken from flat stock, tubular, or structural sections before forming or welding for use in the protective enclosure. Specimens from tubular or structural sections are to be taken from the middle of the side of greatest dimension, not to include welds.

(iii) Glazing shall conform to the requirements contained in Society of Automotive Engineers Standard SAE J674, Safety Glazing Materials.

(iv) Two or more operator exits shall be provided and positioned to avoid the possibility of both being blocked by the same accident.

(2) *Static test performance requirements.* The structural requirements will be generally met if FER >1 and the requirements contained in paragraph (e)(1) of this section are adhered to in both side and rear loads.

(3) *Dynamic test performance requirements.* The structural requirements will be generally met if the dimensions in paragraph (e)(1) of this section are adhered to in both side and rear loads.

(iv) *Field upset test performance requirements.* The requirements of paragraph (e)(1) of this section must be met in both side and rear upsets.

(Sec. 6(b), Pub. L. 91–596, 84 Stat. 1593 (29 U.S.C. 655), Secretary of Labor's Order No. 12–71, 36 FR 8754)

Signed at Washington, D.C., January 24, 1974.

JOHN STENDER,
Assistant Secretary of Labor.

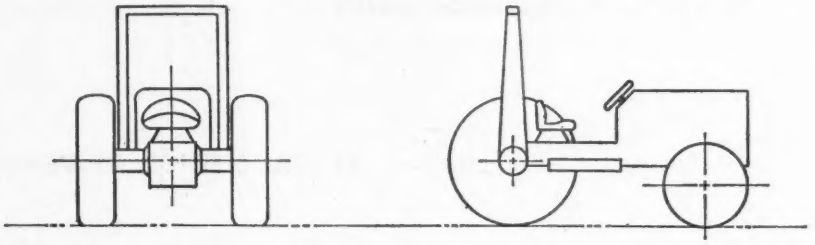

Fig. C-1 TRACTOR WITH TYPICAL PROTECTIVE FRAME

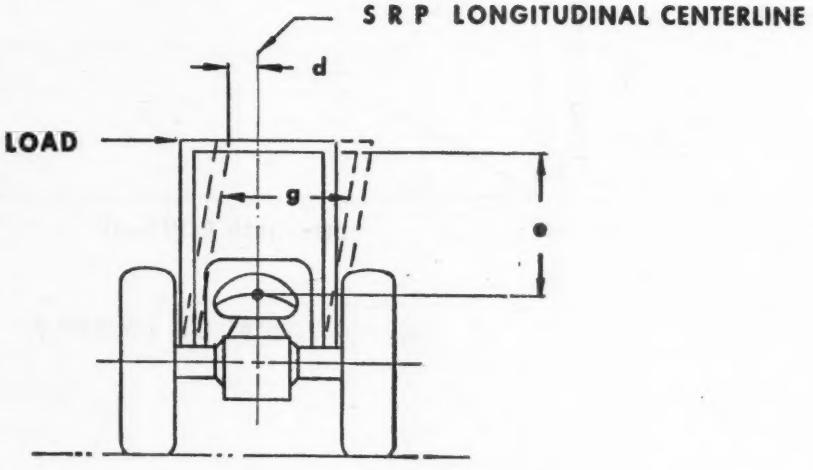

Fig. C-2 SIDE LOAD APPLICATION

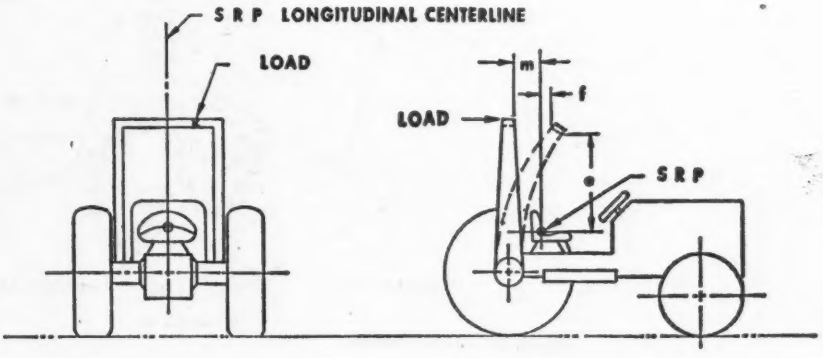

Fig. C-3 REAR LOAD APPLICATION

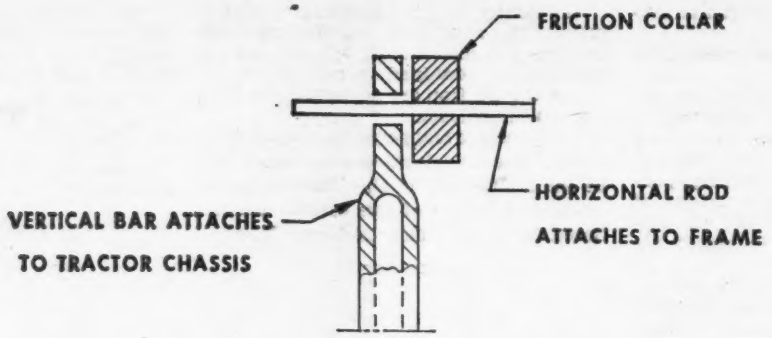

Fig. C-4 TYPICAL METHOD OF MEASURING DEFLECTION

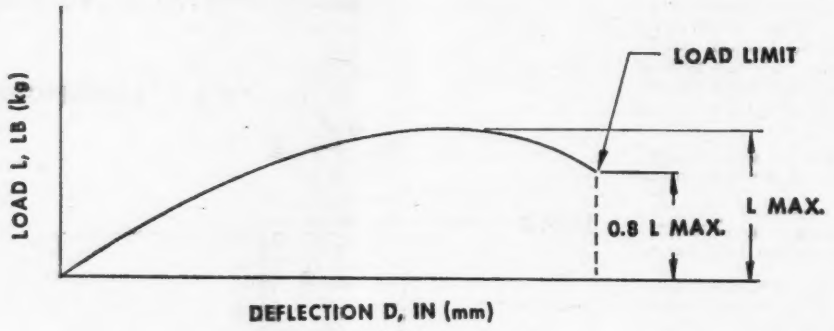

Fig. C-5 TYPICAL L-D DIAGRAM

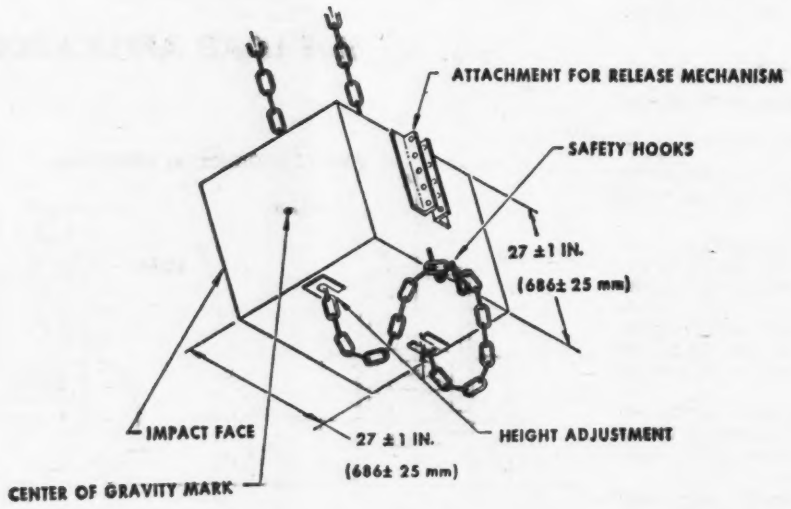

Fig. C-6 PENDULUM

NOTATION OF FORMULAE

$H = 4.92 + 0.00190\ W$ OR ($H' = 125 + 0.107\ W'$)

W = TRACTOR WEIGHT

IN POUNDS (W' = kg)

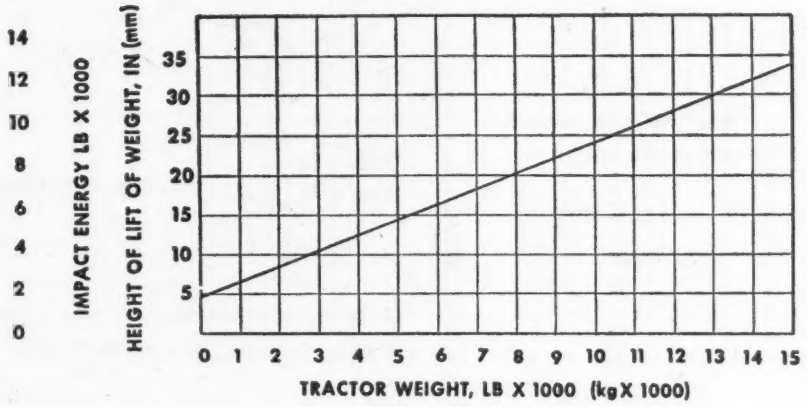

Fig. C-7 IMPACT ENERGY AND CORRESPONDING LIFT HEIGHT OF 4410 LB. (2000 kg) WEIGHT

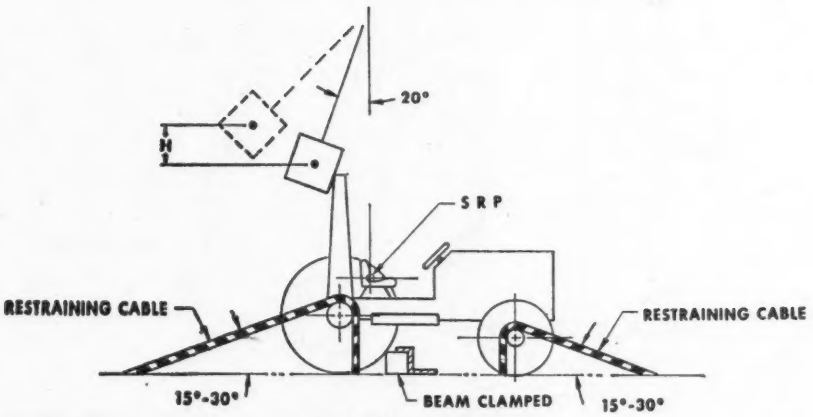

Fig. C-8 REAR IMPACT APPLICATION

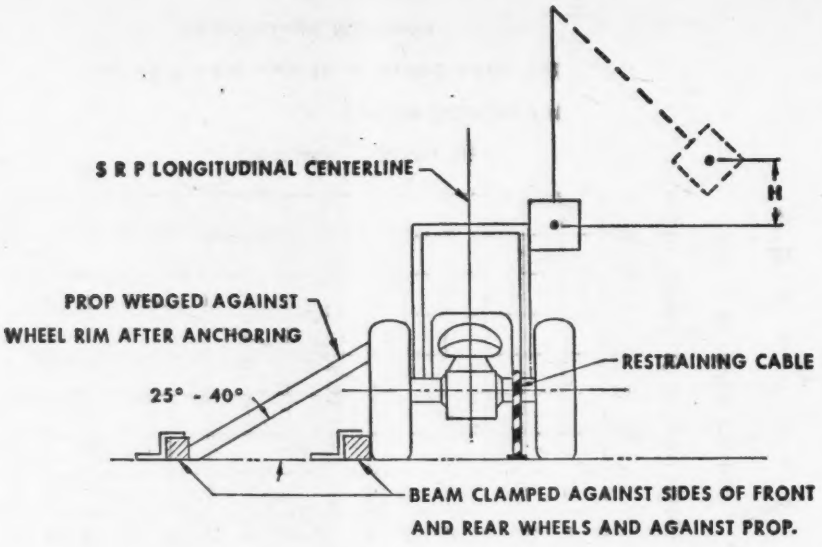

Fig. C-9 SIDE IMPACT APPLICATION

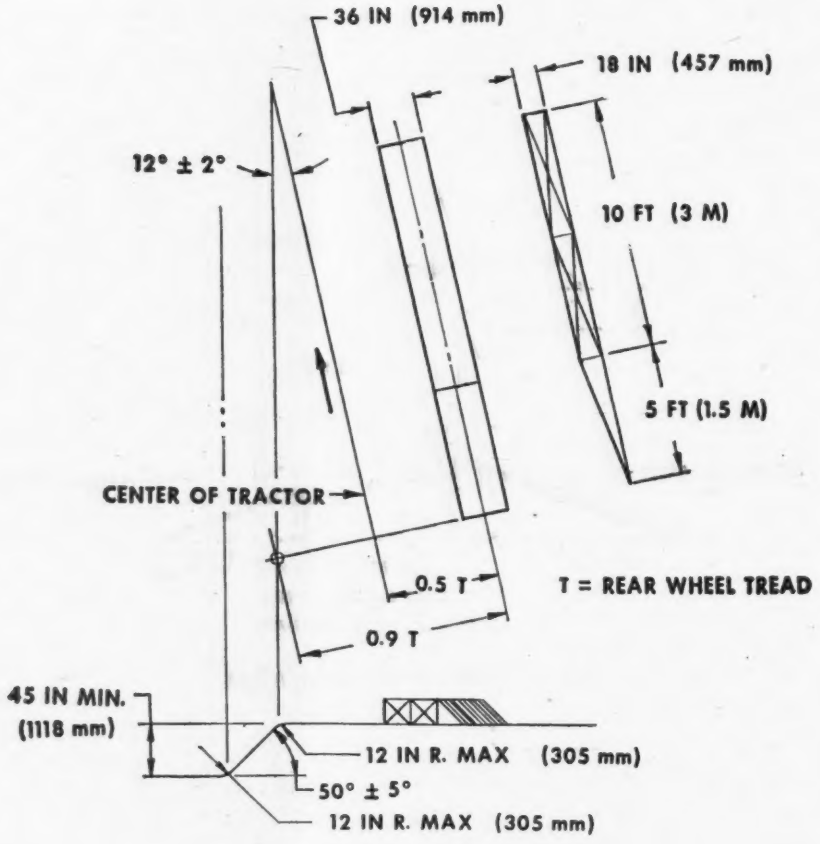

Fig. C-10 SIDE OVERTURN BANK AND RAMP

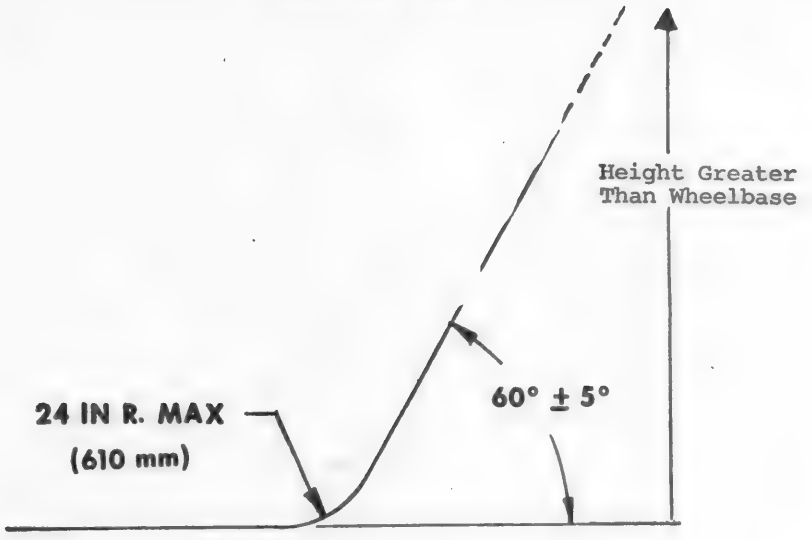

Fig. C-11 **TYPICAL REAR OVERTURN BANK**

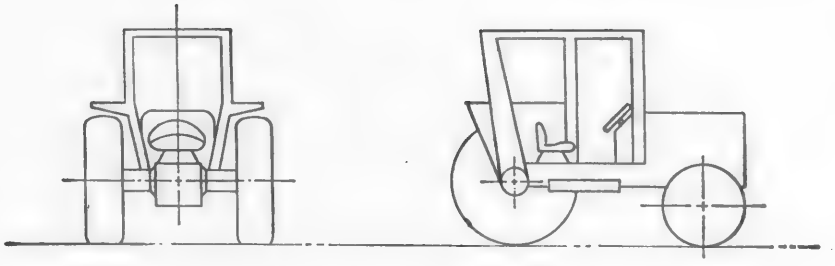

Fig. C-12 **TRACTOR WITH TYPICAL PROTECTIVE ENCLOSURE**

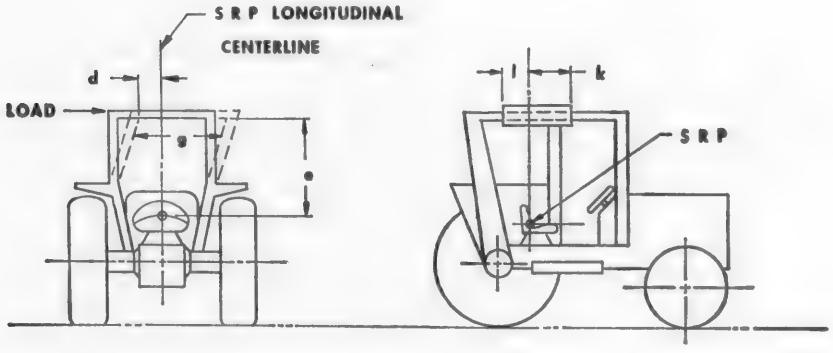

Fig. C-13 **SIDE LOAD APPLICATION**

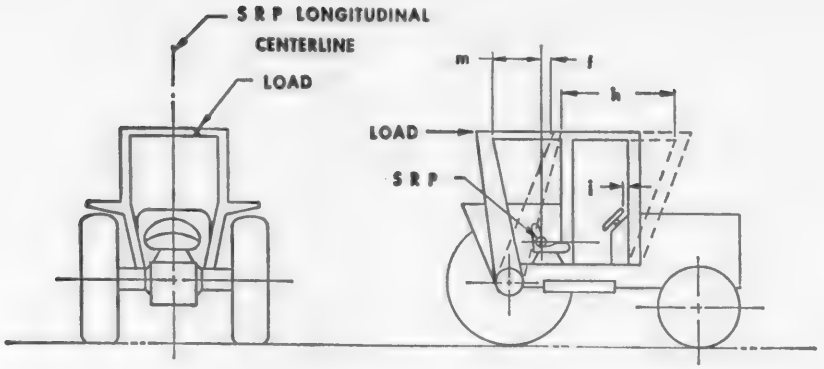

Fig. C-14 REAR LOAD APPLICATION

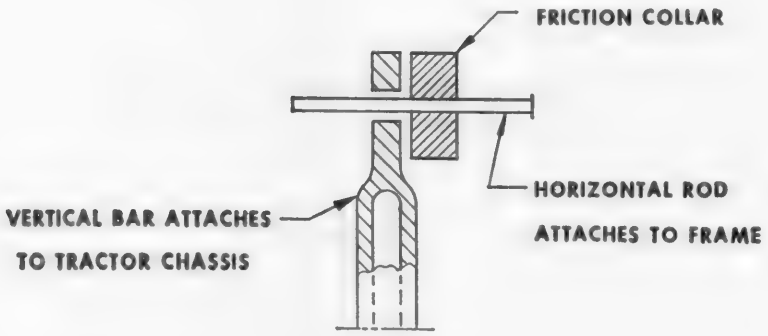

Fig. C-15 TYPICAL METHOD OF MEASURING DEFLECTION

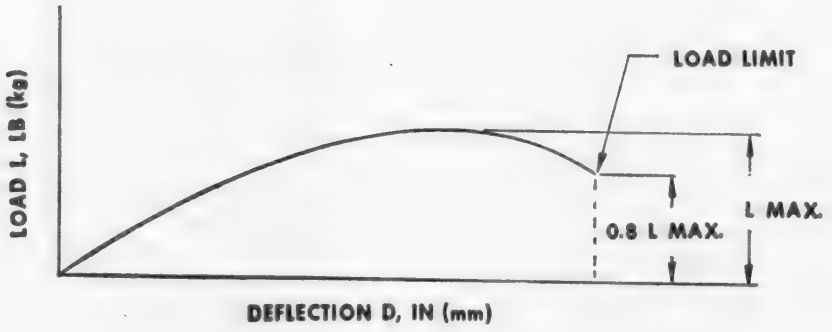

Fig. C-16 TYPICAL L-D DIAGRAM

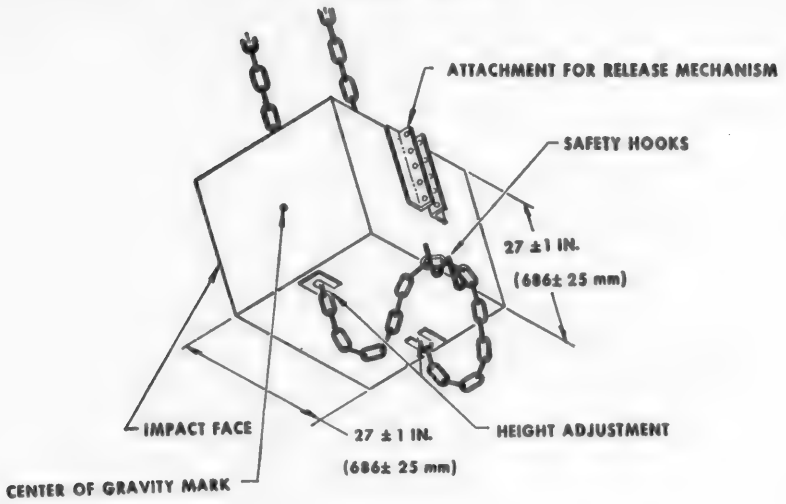

Fig. C-17 PENDULUM

NOTATION OF FORMULAE

$H = 4.92 + 0.00190\ W$ OR $(H' = 125 + 0.107\ W')$

W = TRACTOR WEIGHT IN POUNDS (W' = kg)

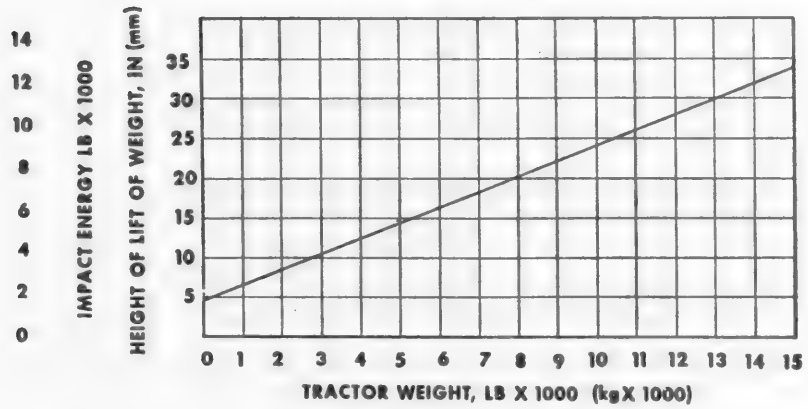

Fig. C-18 IMPACT ENERGY AND CORRESPONDING LIFT HEIGHT OF 4410 LB. (2000 kg) WEIGHT

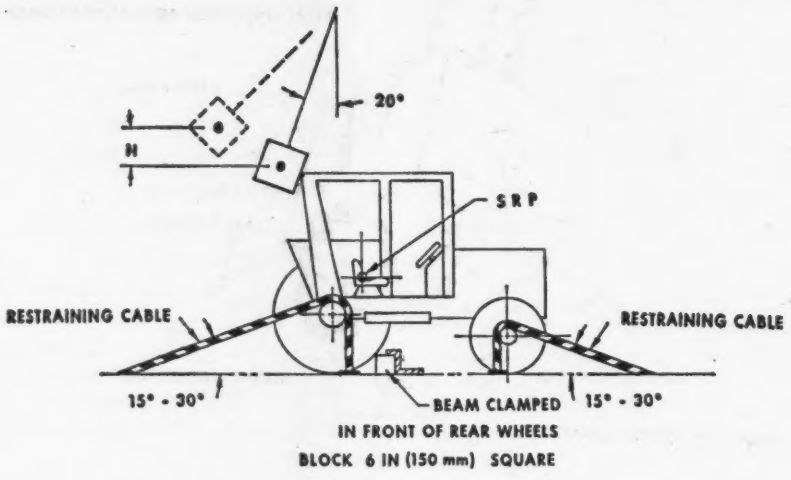

Fig. C-19 REAR IMPACT APPLICATION

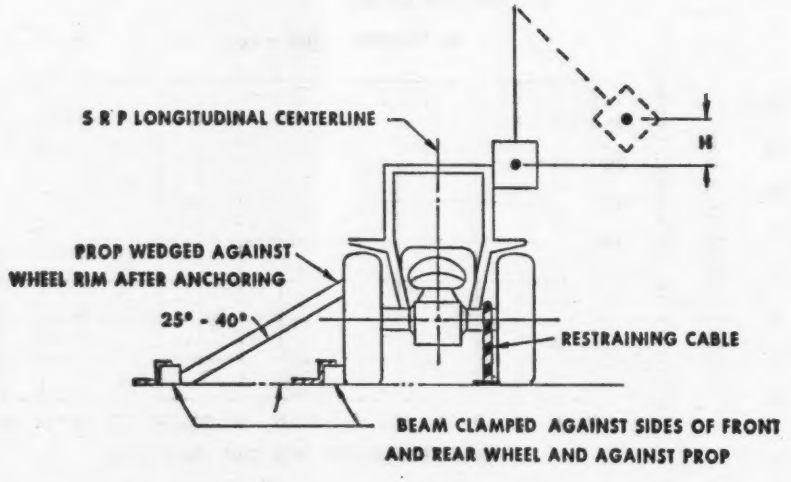

Fig. C-20 SIDE IMPACT APPLICATION

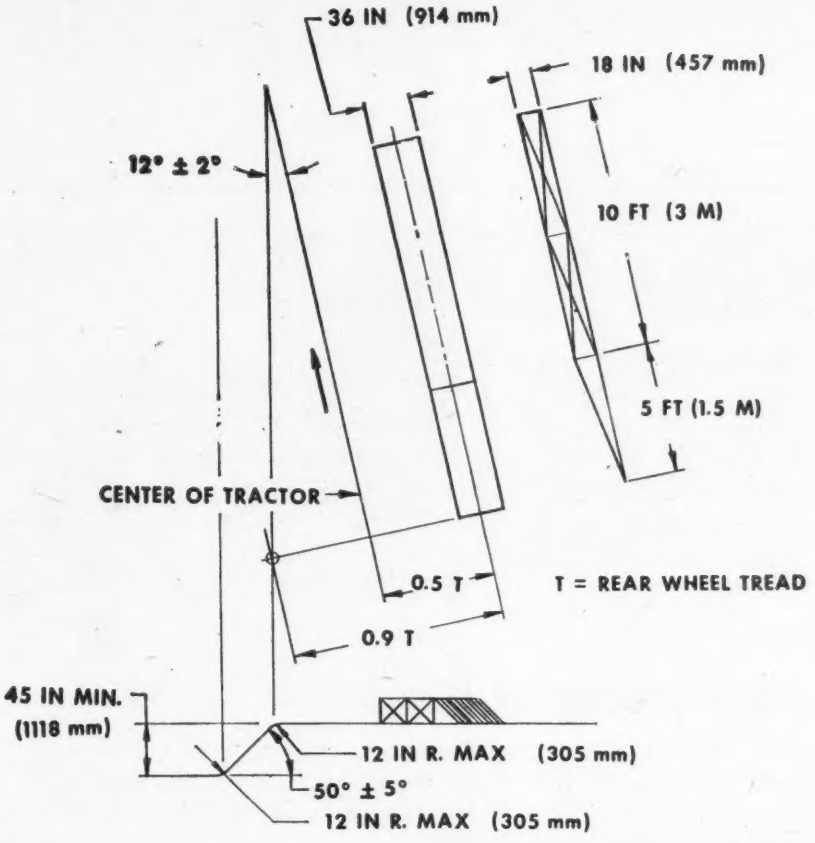

Fig. C-21 **SIDE OVERTURN BANK AND RAMP**

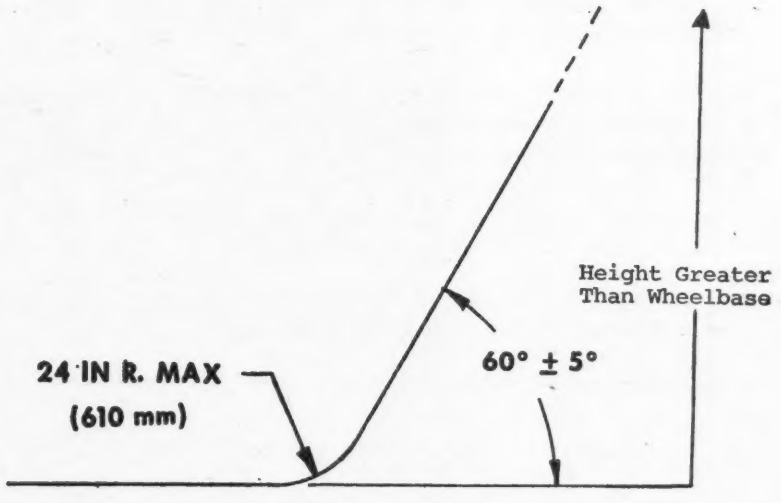

Fig. C-22 **TYPICAL REAR OVERTURN BANK**

[FR Doc.74-2570 Filed 2-1-74;8:45 am]

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